DEVELOPMENT OF SPEED CONTROLLER FOR INVERTER FED INDUCTION MOTOR

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In the name of ALLAH, Most Generous and Most Merciful

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ABSTRACT

Normally variable speed control was performed by some type of d.c. motor. Today, the development of power semiconductors has resulted in the utilization of inverter circuits for variable speed control of induction motor. This project is to develop the application of inverter which can control the speed of induction motor by using PI controller. Inverters are circuit that convert DC to AC. The function of inverter is to create an AC voltage by using a DC voltage source, the voltage source that used DC voltage commonly batteries. Pulse Width Modulation (PWM) technique is considered as one solution for harmonic reduction and increasing the motor efficiency. Previous study regarding the performance on the traditional Pulse Width Modulation (PWM) inverter is carried out and it was found that the performance is not ideal. Therefore an improvement on the traditional PWM inverter is carried out by inserting a Proportional Integral (PI) controller to regulate and stabilize the output voltage of the inverter. This work was applied close-loop variable speed drive for single-phase induction motor using voltage control. The proposed drive system is simulated using Matlab/ Simulink, its results were compared with the hardware experimental results. The simulation and laboratory results proved that the drive system could be used for the speed control of a single phase induction motor with wide speed range.

ABSTRAK

Biasanya kawalan kelajuan boleh laras dilakukan oleh beberapa jenis dc motor. Sekarang ini, perkembangan semikonduktor kuasa telah mengakibatkan penggunaan litar penyongsang untuk kawalan kelajuan boleh laras projek motor aruhan. Ini adalah untuk mengembangkan aplikasi penyongsang yang boleh mengawal kelajuan motor aruhan dengan menggunakan teknik PWM. Penyongsang adalah litar yang menukarkan DC ke AC. Fungsi penyongsang adalah untuk menghasilkan voltan AC dengan menggunakan sumber voltan DC, sumber voltan yang digunakan oleh voltan DC biasanya bateri. Kaedah permodulatan lebar denyut (PLD) dianggap sebagai salah satu penyelesaian untuk mengurangkan harmonik dan meningkatkan kecekapan motor. Kajian tentang ciri-ciri dan prestasi sesebuah penyongsang tradisi telah dibuat dan didapati prestasinya tidak begitu memuaskan. Justeru pengawal PI telah digunakan dalam Pemodulatan Lebar Denyut (PWM) penyongsang bagi mengawal dan menstabilkan voltan keluaran penyongsang. Kerja ini mengaplikasikan kawalan kelajuan boleh laras gelung tertutup untuk motor aruhan satu fasa menggunakan kaedah kawalan voltan. Sistem pemacu yang telah dicadangkan telah disimulasikan menggunakan Matlab /Simulink. Keputusannya telah dibandingkan dengan hasil yang diperolehi melalui kaedah eksperimen menggunakan perkakasan yang sebenar. Keputusan simulasi dan eksperimen di dalam makmal membuktikan bahawa sistem pemacu tersebut boleh digunakan untuk mengawal kelajuan motor aruhan satu fasa dengan julat kelajuan yang lebih besar.

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S - Apparent power

V - Voltage

Vo - Output voltage

Vin - Input voltage

Vdc - DC supply voltage

Vrms - rms voltage

Vref - Reference voltage

I - Current

Io - Output current

Iin - Input current

Irms - rms current

R - Resistor

f - Switching frequency

fLC - Cut-off frequency

ma - Modulation index

mf - Modulation frequency

L - Inductor

C - Capacitor

PWM - Pulse Width Modulation

THD - Total harmonic distortion

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

This chapters are mainly discuss about application of inverter and advantages of the PWM inverter and also the development inverter by using PI controller. The problem, objectives, scopes, methodology and thesis outline also presented in this chapter.

1.2 Overview of the Project

Inverters are circuits that convert direct current (DC) to alternating current (AC). Usually inverters are used to transfer power from a DC source to an AC load. Inverters are mainly used in application such as adjustable-speed AC motor drives, uninterruptible power supply (UPS), and AC appliances run from an automobile battery.

Although inverters are used to convert DC to AC, the output of the inverters usually contains very high total harmonics distortion (THD). Hence measures used to reduce the THD at the output become the concern of the development of inverters.

PWM inverters are members of the inverter family. PWM inverters are favorable in many inverter circuits because PWM inverters manage to eliminate harmonics in a relatively easier way as compare to traditional square-wave inverters. The main advantage of PWM inverter is to shift all the harmonics into a much higher frequency, causing the filter design become easier than the square-wave inverters.

In order to successfully produce output with low THD, a unipolar switching scheme is employed in design of PWM inverter. Besides a linear PI controller is proposed to stabilize the voltage at the output.

1.3 Problem Statement

PWM inverters usually contain higher THD before the filtering process. However, PWM inverters shift the harmonics into higher frequency hence a relatively easier filter can be designed i.e. the cut-off frequency can be placed in the range of kHz hence allowing the components size of LC filter become smaller. Due to rapid development of modern technologies, the control methods that are used in PWM inverters can be categorized into 3 groups, which are model based, non-model based, and mix-based. PI controller being the model-based controller is used in stabilizing the output voltage of the PWM inverters.

1.4 Objectives of the Project

I. To develop inverter for single phase induction motor applications that can generate variable voltages
II. To enhance the performance of a typical PWM inverter using PI controller.
III. Design circuit and analyze the switching characteristics of pulse width modulated inverter.

1.5 The scopes of the Project.

After intensively reviewed on the single-phase unipolar inverter, there are many issues need to be tackled in order to achieve a preliminary objective. The scopes of this thesis are used for the guideline of the project. The project scopes are as follows:

I. Read all significant references and analyse the literature reviews about the operation of inverter, operation of PWM, driver circuit, power circuit.

II. Design a simulation circuit by using MATLAB/SIMULINK software part by part according to the theories and methods that gain from the literature review. Then simulated and analysis the output waveform.

III. Construct the circuit on breadboard based on collected data from simulation part and literature reviews.

1.6 Methodology

The procedure of the analysis is the important factor to ensure that project is completely done as expected, because it is necessary to have an efficient plan and it will help to guide into the target to achieve the objective. There are two parts of study in this project. The first part is simulation part and the second part is experimental part.

1.7 Thesis Outline

Chapter 1 discuss on the background of the project, objectives, scope of the project, methodology and also the thesis outline.

Chapter 2 focuses on literature reviews of this project based on journals and other references.

Chapter 3 mainly discuss on the system design of the project. Details on the progress of the project are explained in this chapter.

Chapter 4 presents the results of the project. The discussion focused on the result based on the experiment.

Chapter 5 concludes overall about the project. Obstacle faces and future recommendation are also discussed in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the overview and theories of several fields involve in this dissertation is discussed. These concepts will further help us to understand the upcoming discussion on PWM inverter and its implementation. This chapter also attempts to give brief explanations and elucidate the control theory of PWM inverter. Theory and the operation of the PWM inverter with linear PI controller are discussed in this chapter. Last but not least, a brief review is done on the different controller for PWM inverter.

2.2 AC Motor and Loads

An inverter is an electronic device which inverts DC energy (the type of energy found in batteries) into AC energy. Household appliances such as refrigerators, TVs, lighting, stereos, computer etc., all run off of AC electricity [1]. An AC motor is an electric motor that is driven by an alternating current. The motor is connected to the mains through an AC switch. The AC voltage varies across the motor in phase control mode by means of a microcontroller, which sets the triggering time. The application of AC motor load is refrigerators, TVs, lighting, computer and washing machines power tools and food processors.

Besides that, small single-phase AC motor are usually used to power mechanical clocks, audio turn tables, and tape drives; formerly they were also much used in accurate timing instruments such as strip-chart recorders or telescope drive mechanisms[1]

2.2 Unipolar PWM inverter

Pulse Width Modulation (PWM) provides a way to decrease the THD of the output signal. In PWM, the amplitude of the output voltage can be controlled with the modulating waveforms. For a PWM inverter, it required a reference signal (usually a sinusoidal signal) and a carrier signal (a triangular wave that controls the switching frequency). The operation of a unipolar PWM inverter is first comparing the reference voltage (Vref) to a reference triangular waveform (Vtri). The principle is shown in Figure 2.1 below [2].

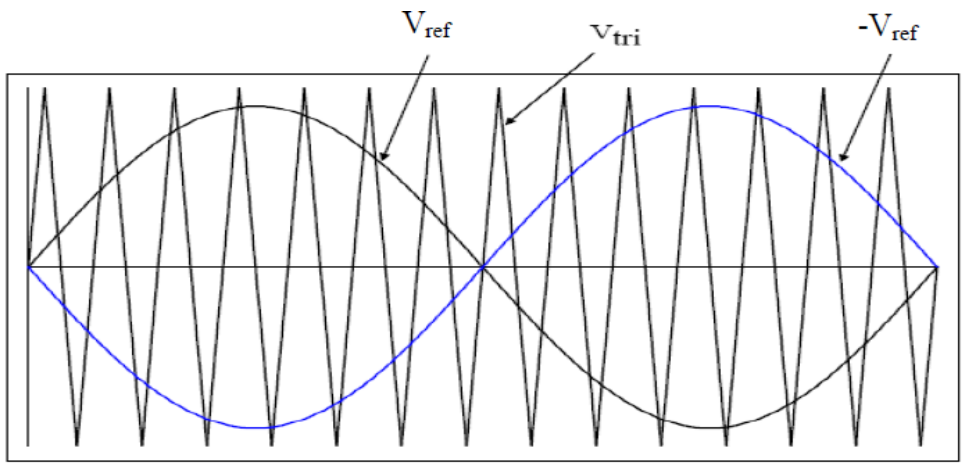

Figure 2.1: Basic PWM Principle of Operation

Based on Figure 2.1, ma = 0.9 where ma is the ratio of peak control voltage to peak triangle voltage that is ——. The logic is used to operate the four switches in the H-Bridge configuration of Figure 2.2 is as follows [2]:

i. Vref > Vtri , close switch A+, open switch A– , so voltage Va = Vdc
ii. Vref < Vtri , open switch A+, close switch A– , so voltage Va = 0
iii. –Vref > Vtri , close switch B+, open switch B– , so voltage Vb = Vdc
iv. –Vref< Vtri , open switch B+, close switch B– , so voltage Vb = 0

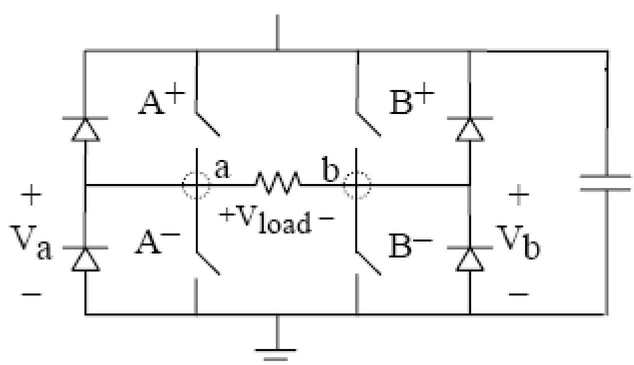

Figure 2.2: Four MOSFET Switches (A+, A-, B+, B-) Configured as an H-Bridge

The resulting voltage across the load (Vab) under unipolar switching scheme is shown in Figure 2.3 below. [2]

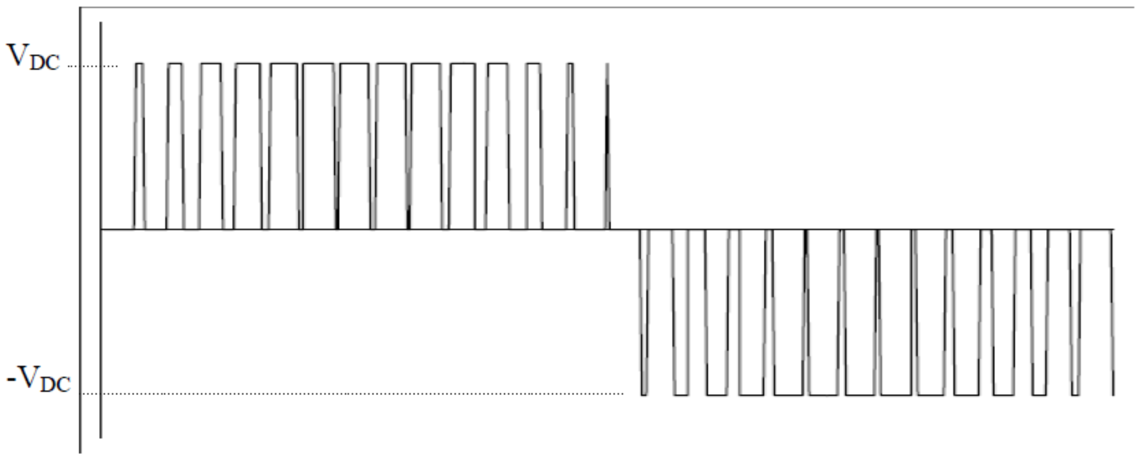

Figure 2.3: Load voltage at ma = 0.9

The output voltage shown in Figure 2.3 before filtering contains very high THD. Hence a filter has to be designed to eliminate the harmonics at the output signal. For unipolar PWM inverter, the harmonics only exist in the order of 2mf, 4mf, 6mf and others, where modulation frequency, =——., where ftri is the frequency of triangular signal and fref is the frequency of the sinusoidal signal respectively. Since in most application, high switching frequency around 20 kHz is employed in PWM inverter, thus the harmonics are all shift to very high frequency allowing the design of LC filter becoming easier.

2.3 Total Harmonic Distortion (THD)

Total Harmonic Distortion is a term that is used to quantify the non-sinusoidal property of a waveform. Smaller THD allows the components in a loudspeaker, amplifier or microphone or other equipment to produce a more accurate reproduction in electronics and audio media [3]. Since the objective of the inverter is to use a DC voltage as input source to supply a load requiring AC voltage and current, the quality of the AC output can be described in THD terms. Table 2.1 shows the Normalized Fourier Coefficient Vn/Vdc for unipolar PWM inverter. [6]

Table 2.1: Normalized Fourier Coefficient Vn/Vdc for Unipolar PWM Inverter.

ma	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
n = 1	1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.30	0.20	0.10
n = 2mf±1	0.18	0.25	0.31	0.35	0.37	0.36	0.33	0.27	0.19	0.10
n = 2mf±3	0.21	0.18	0.14	0.10	0.07	0.04	0.02	0.01	0.00	0.00

2.4 State Space Inverter Model

PWM inverter is non-linear in nature due to the existence of the solid state switches. Hence both linearization and averaging of the PWM are the initial steps before designing suitable controller for the inverter. Referring to Figure 2.4 below, with the assumption of switching frequency is more than 10 kHz, the PWM inverter can be represented by a DC voltage source, Va with a value of Vcont * KPWM where KPWM = Vdc/Vtri. By choosing the inductor current, iL and output voltage, Vout as the system variables, the state space model of the equivalent circuit can be formed as shown in Figure 2.5. The state-space inverter model shown in Figure 2.5 is the basic to develop a controller for the PWM inverter.

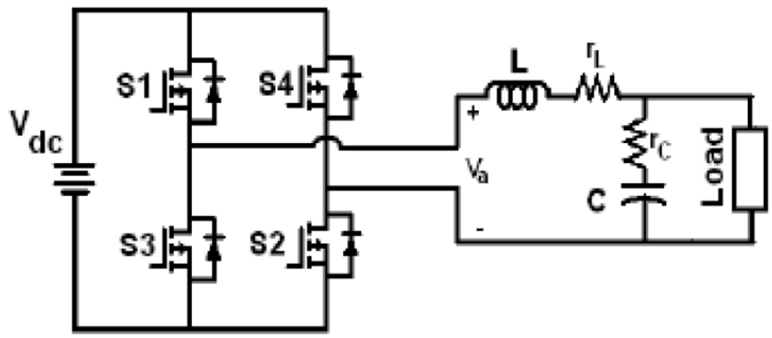

Figure 2.4: Typical Single Phase Inverter Circuit

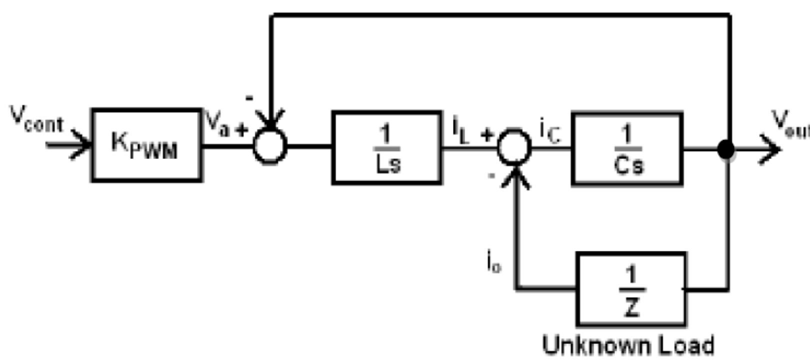

Figure 2.5: State-Space Inverter Model Block Diagram

2.5 Linear PI Controller

The controller for PWM inverter can be categorized into 3 groups which are model-based, non-model based and mix based [1]. Figure 2.6 shows the types of controller available in PWM inverter.